

Cool Coatings for Cool Cars: A measure to cool the globe

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Sizing of A/C

- Vehicle heat loads (what heats cabin)
 - Solar gain through glazing
 - Conduction through shell (driven by sun, ambient air)
 - Engine
 - Occupants
- Passenger car A/C sizing parameters
 - Dominated by solar, convective/conductive loads
 - Soak temperature $T_{\text{soak}} = T_{\text{soak}}(\text{solar gain}, T_{\text{ambient}})$
 - Desired cool-down time τ
 - A/C capacity = $f(T_{\text{soak}}, \tau)$



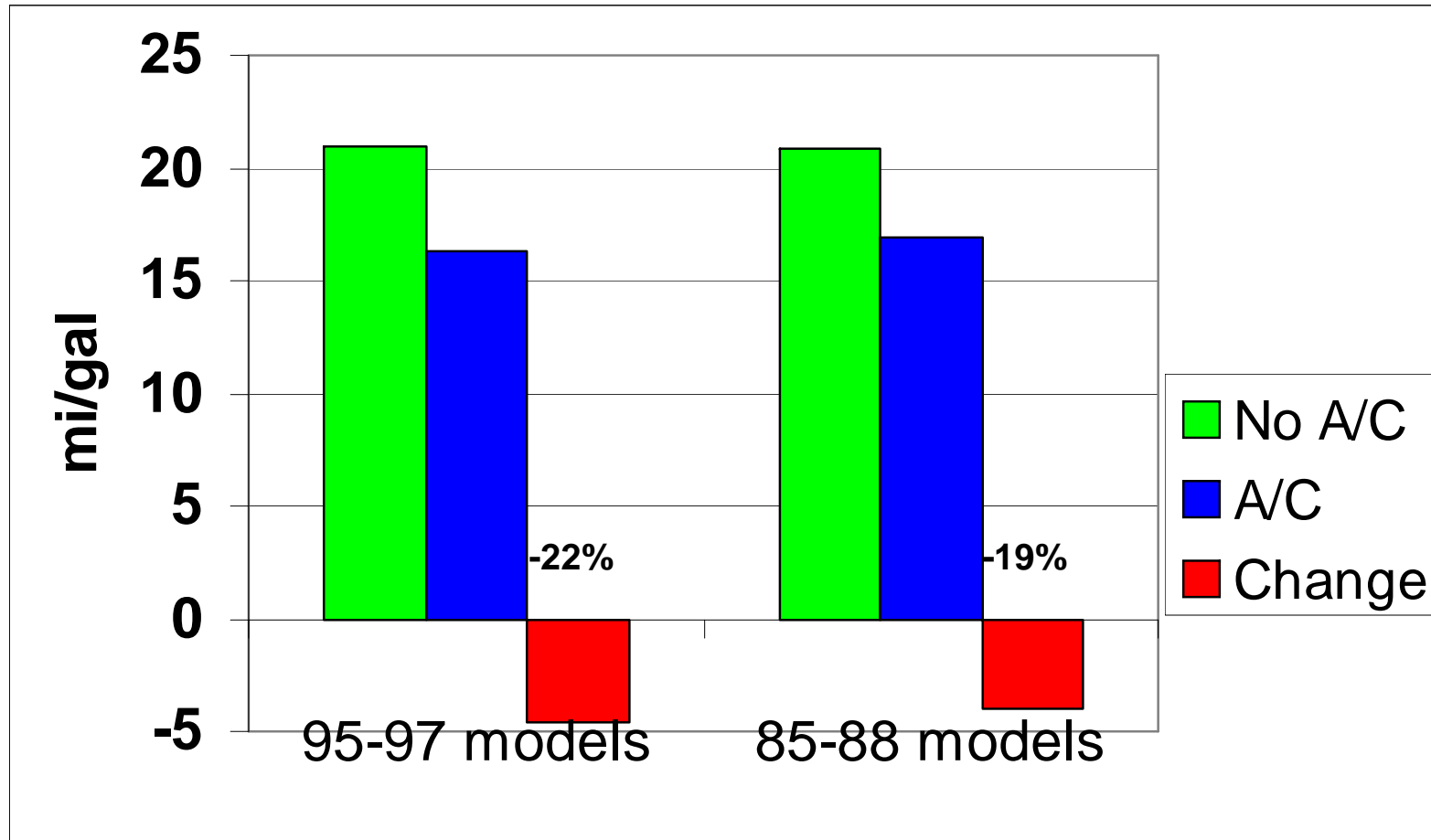
Technologies to improve A/C performance

- Enhanced mechanical efficiency
 - Controls
 - Drives
 - Components
- Soak (stationary) load reduction
 - Glazing (low- ϵ , electrochromics, reflective hydrides, liquid crystals, suspended particle displays, photochromics, thermochromics)
 - **Low-absorptance shell coatings (cool colors)**
 - Ventilation
- Moving load reduction
 - Glazing
 - Engine firewall insulation

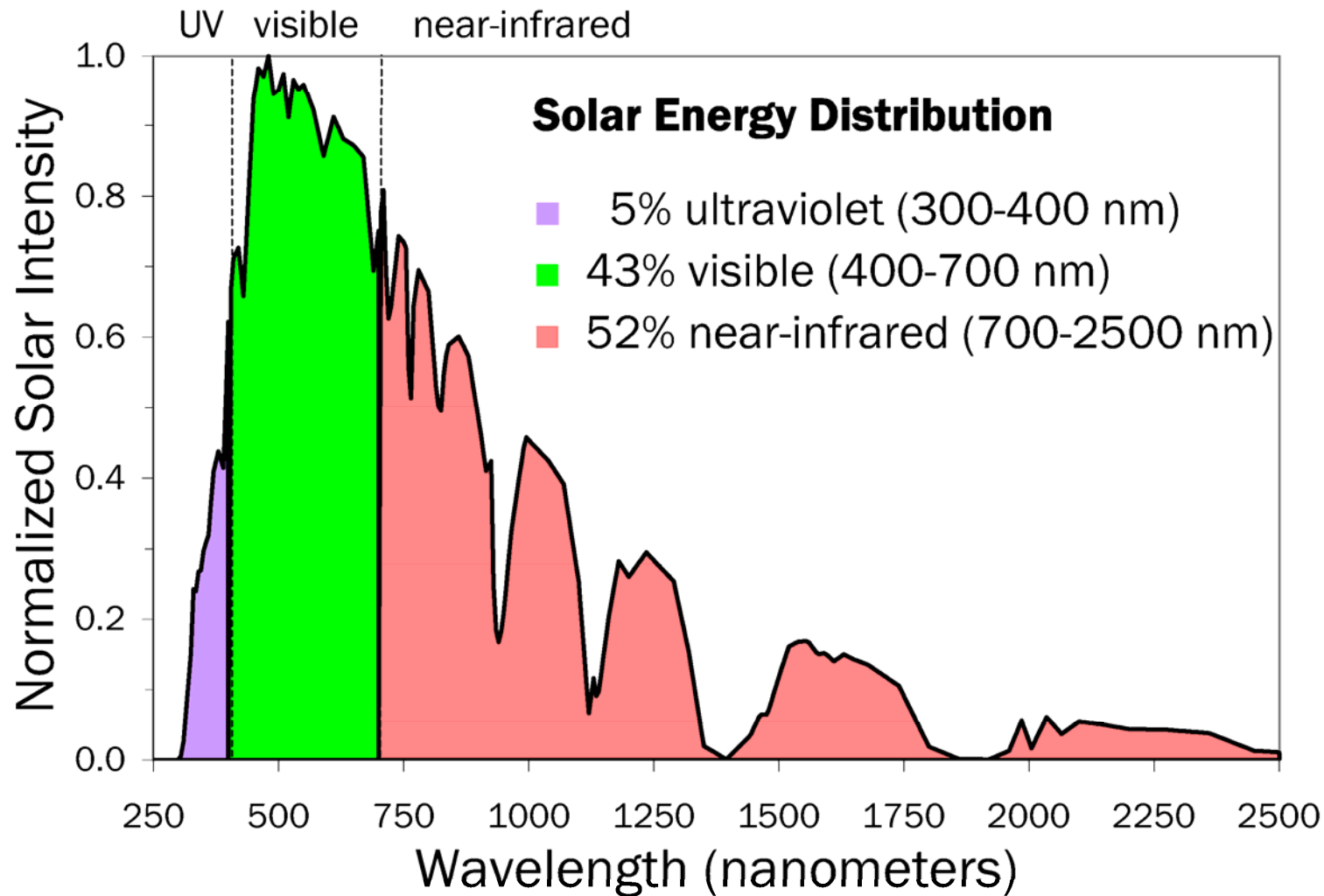


A/C effect on fuel efficiency

(Source: Bevilacqua, 1999)



Most sunlight (57%) is invisible

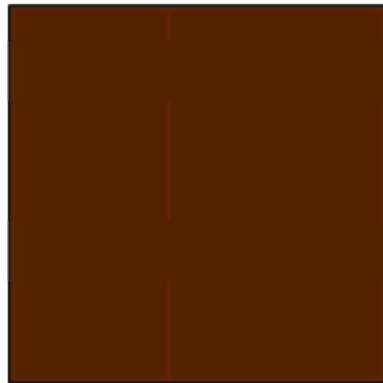


Reducing solar absorptance using NIR-reflective pigments

brown metal panel

COURTESY
BASF CORPORATION

cool

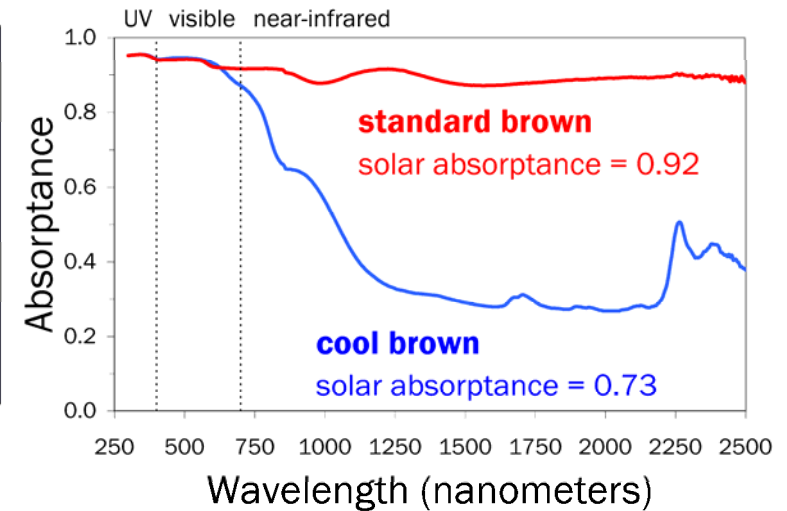


solar absorptance = 0.73
thermal emittance = 0.85
roof temp - air temp = 36°C (65°F)

standard

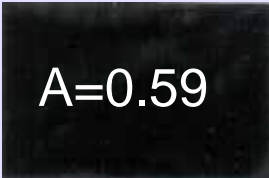
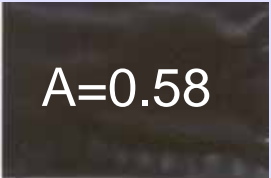
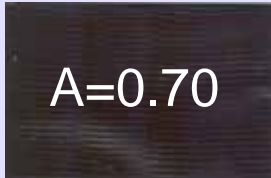
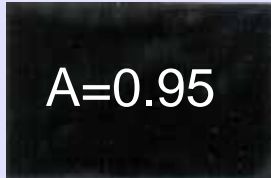


solar absorptance = 0.92
thermal emittance = 0.85
roof temp - air temp = 45°C (81°F)



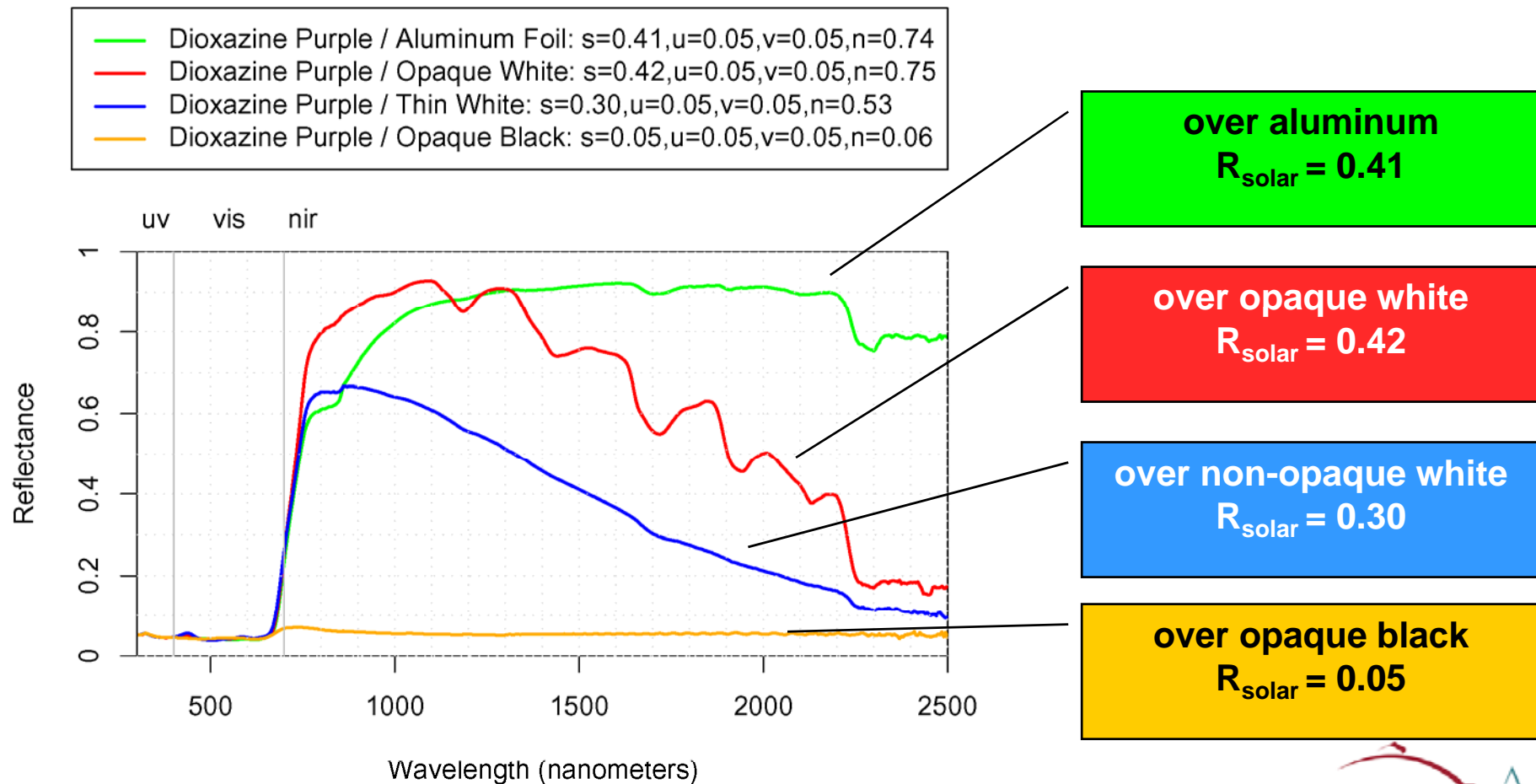
Reducing solar absorptance (A) using bilayer coatings

- Top coat: dark pigment with low NIR absorptance (e.g., dioxazine purple)
- Undercoat: pigment with high NIR reflectance (e.g., titanium white)

			
A=0.59	A=0.58	A=0.70	A=0.95
purple over aluminum foil	purple over opaque white paint	purple over non-opaque white paint	purple over opaque black paint

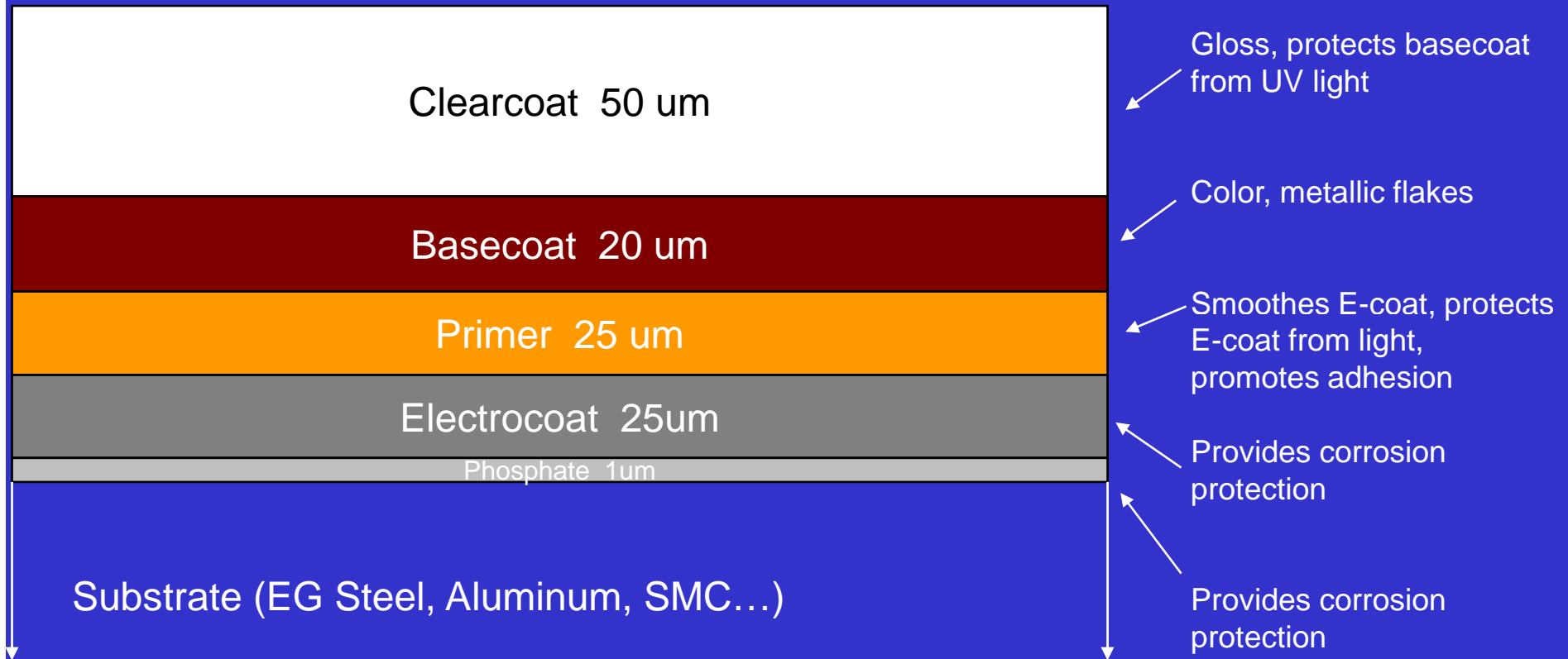


Solar reflectance of bilayer purple coatings



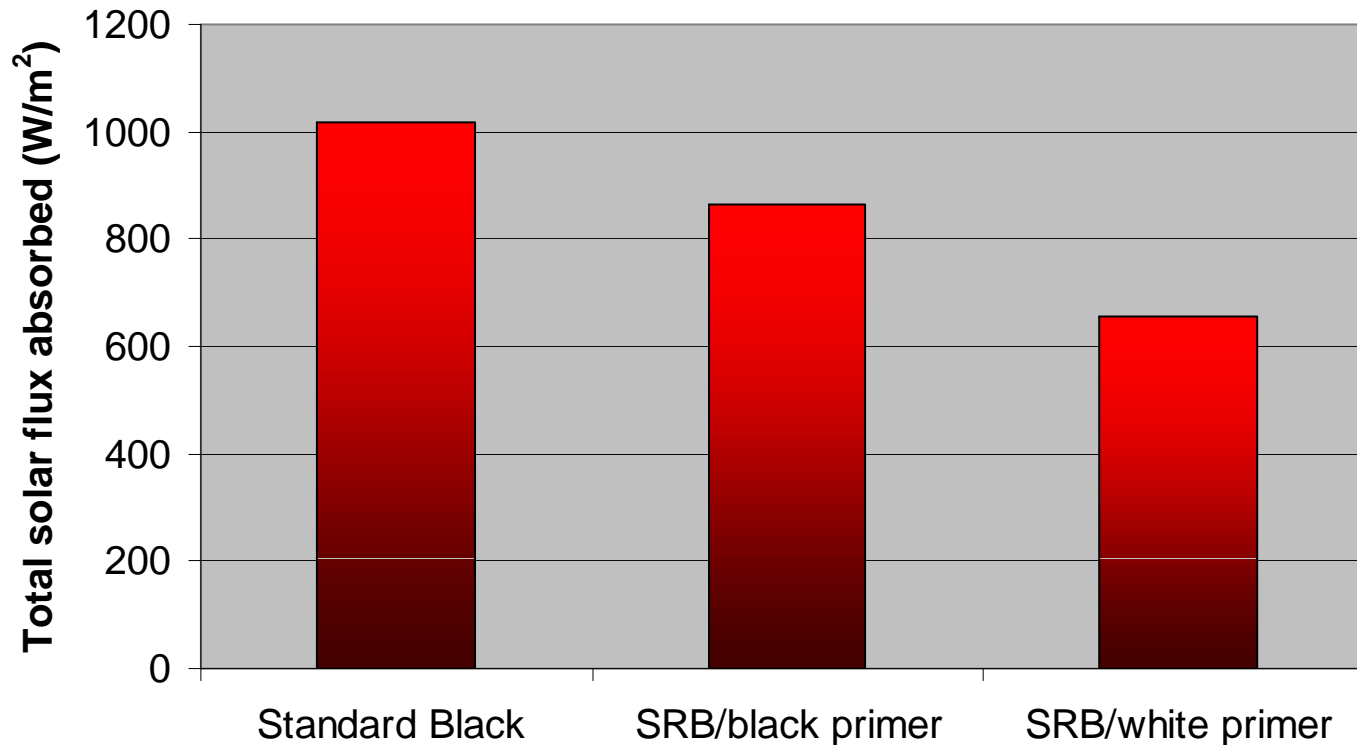
Automotive Paint System

(Courtesy: Nichols, Ford Motor Company)



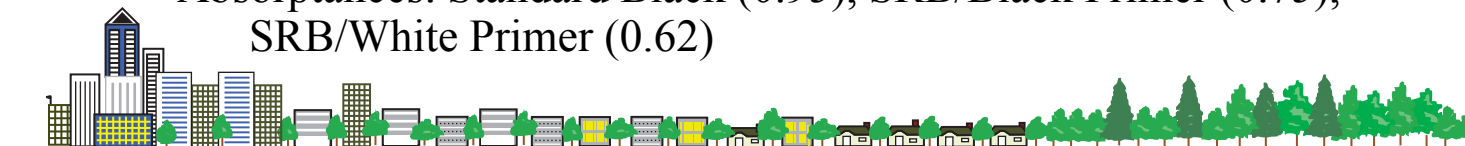
Effect of primer color on solar gain

(Courtesy: Hoke and Greiner, Ford Motor Company)

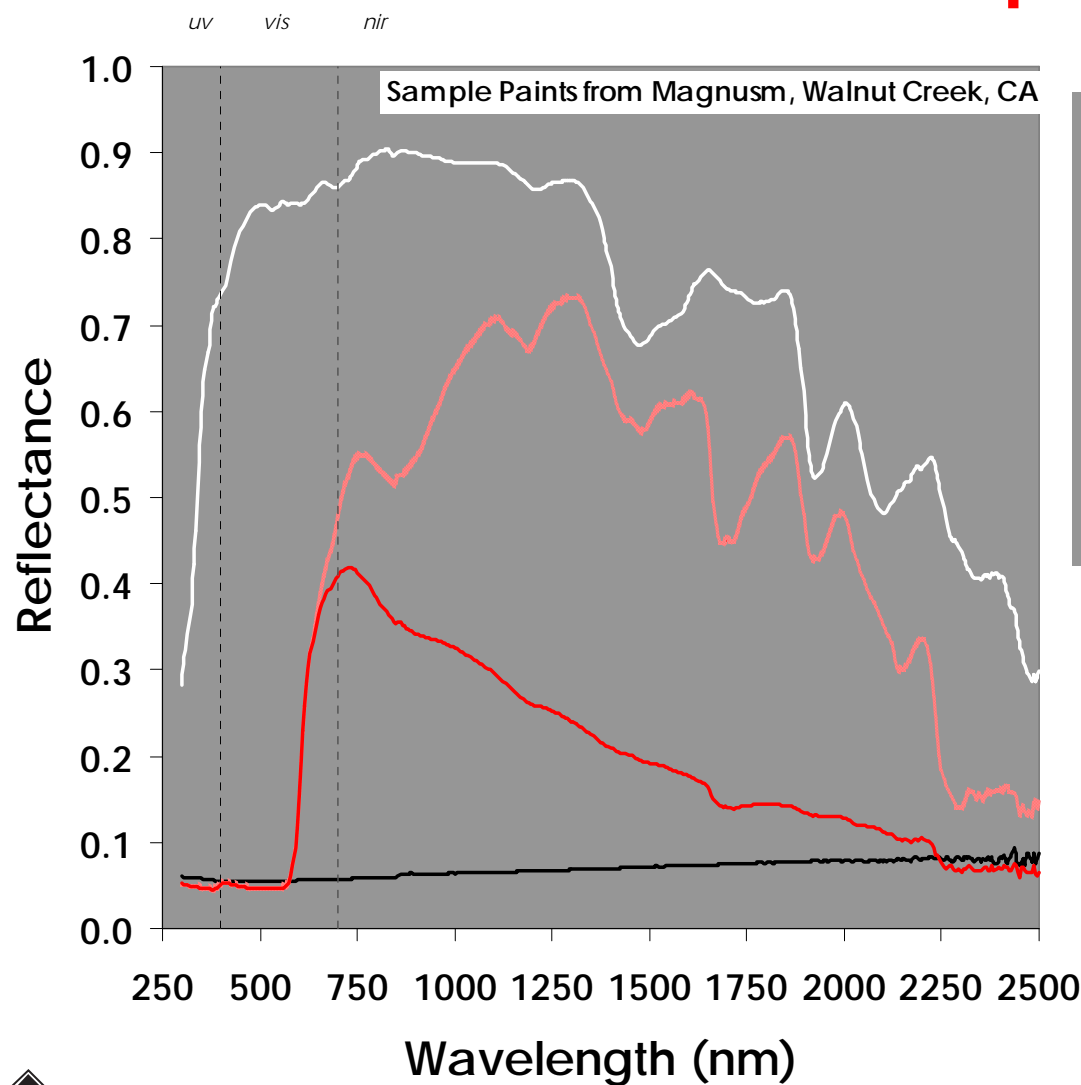


SRB: Solar Reflective Black

Absorptances: Standard Black (0.95), SRB/Black Primer (0.75),
SRB/White Primer (0.62)



Reflectance of sample car paints



- EZ Blank, White, $R = 0.83$
- EZ Blank, Black, $R = 0.06$
- Red on White b.g, $R = 0.37$
- Red on Black b.g, $R = 0.22$



Market deployment of cool color cars



- Toyota experiment (surface temperature 10 K cooler with cool coatings.)
- Ford is also working on a similar technology.

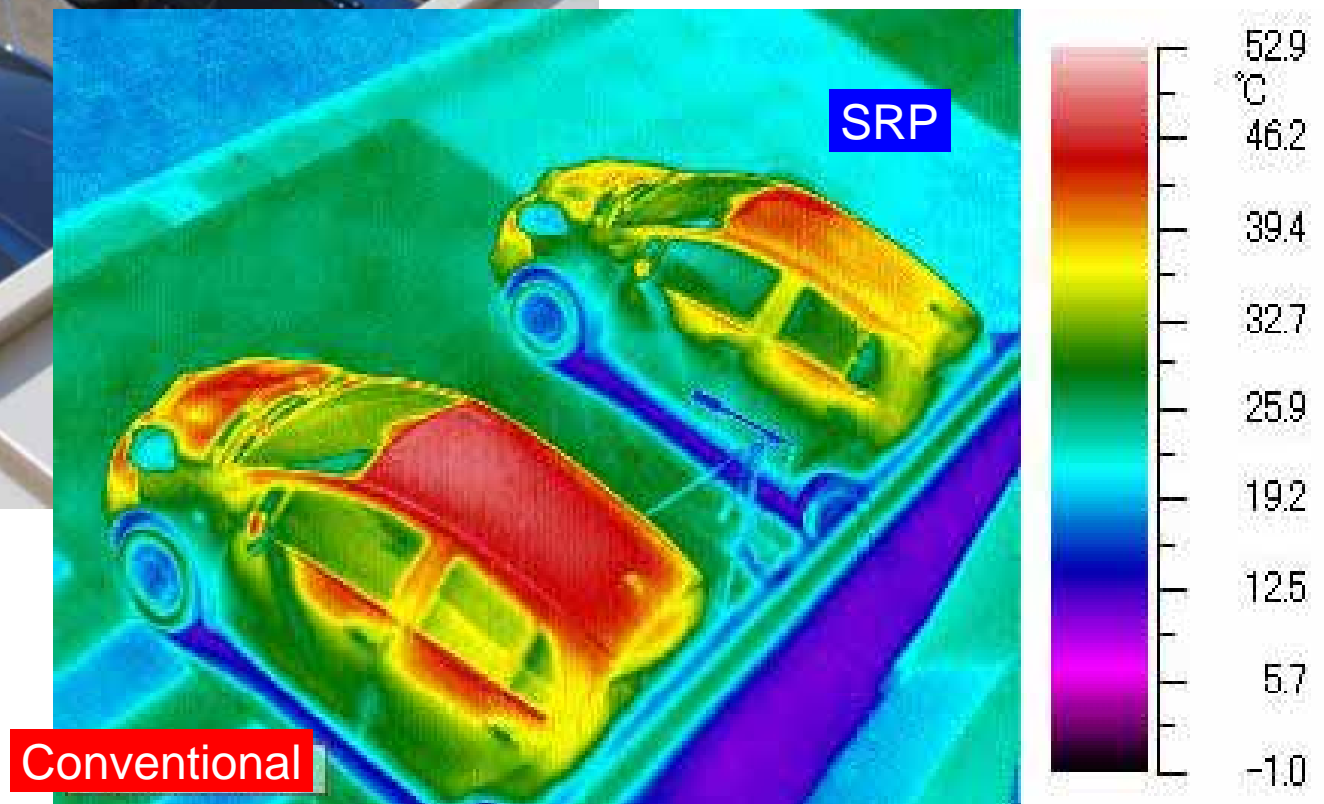


Cooling load reduction

◆ Measurement: Thermograph (2006/01/29)

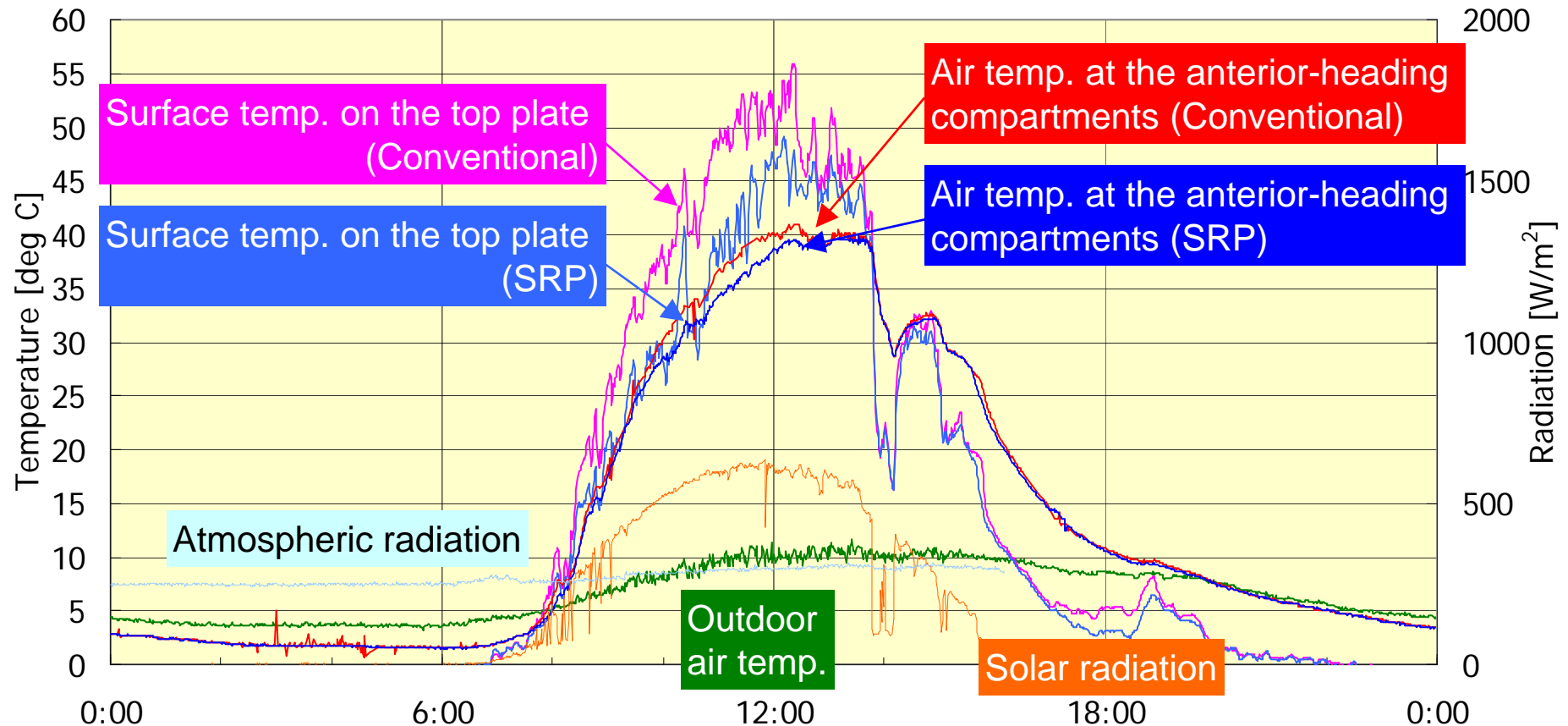


Surface temperature
was suppressed.



Cooling load reduction

◆ Measurement: Air temperature in cars (2006/01/27)



- Air temp. in conventional car went to as high as 40 deg C in the daytime.
- SRP car suppressed an increase in surface temp. by 5~10 deg C.
- Air temp. in SRP car also was reduced by a maximum of 3.9~1.6 deg C.

Effect of A/C on fuel consumption

	US	Cal.
No. of Vehicles (10^6)	213	26
Miles/year/car (10^3)	12	12
Fuel Eff [mpg]	20	20
Annual fuel use [10^9 gal]	130	15
Annual fuel expense at 2.5 \$/gal [\$B]	230	38
Reduced efficiency due to A/C	15%	15%
% time AC runs	50%	50%
A/C contribution to fuel use [10^9 gal]	9.6	1.2
A/C contribution to fuel expense [\$B]	24	3
A/C contribution to CO ₂ [MT]	84	10



Benefits of 2.8K (5°F) reduction in soak temperature

	US	Cal.
Reduction in AC capacity	11%	11%
Improvement in mpg	1.8%	1.8%
Reduced NOx emission	4.5%	4.5%
Reduced fuel expense (\$M)	2876	346
Reduced CO emission (tonne/day)	978	117.8
Reduced NOx emission (tonne/day)	103	12.4
Reduced NMHC emission (tonne/day)	18	2.2
Reduced CO2 emission (MT/year)	20.2	2.4

